

2014 INTERNATIONAL WORKSHOP ON ENVIRONMENT AND ALTERNATIVE ENERGY

Increasing Space Mission Resiliency through Sustainability

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GSyF
*Equipamentos
para Energia*

ISEL
INSTITUTO SUPERIOR DE
ENGENHARIA DE LISBOA



Production of renewable synthetic fuels from electricity using ELECTROFUEL[®] concept

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FUNDAÇÃO
LUSO-AMERICANA


COMPETE

 **QUADRO
DE REFERÊNCIA
ESTRATÉGICO
NACIONAL**


UNIÃO EUROPEIA
Fundo Europeu
de Desenvolvimento Regional

Contents...



- ELECTROFUEL[®] concept
- Syngas applications
- Syngas to liquid fuels
- Preliminary tests
- Future work
- Conclusions

Synthetic Fuels...



... are able to cut oil dependence

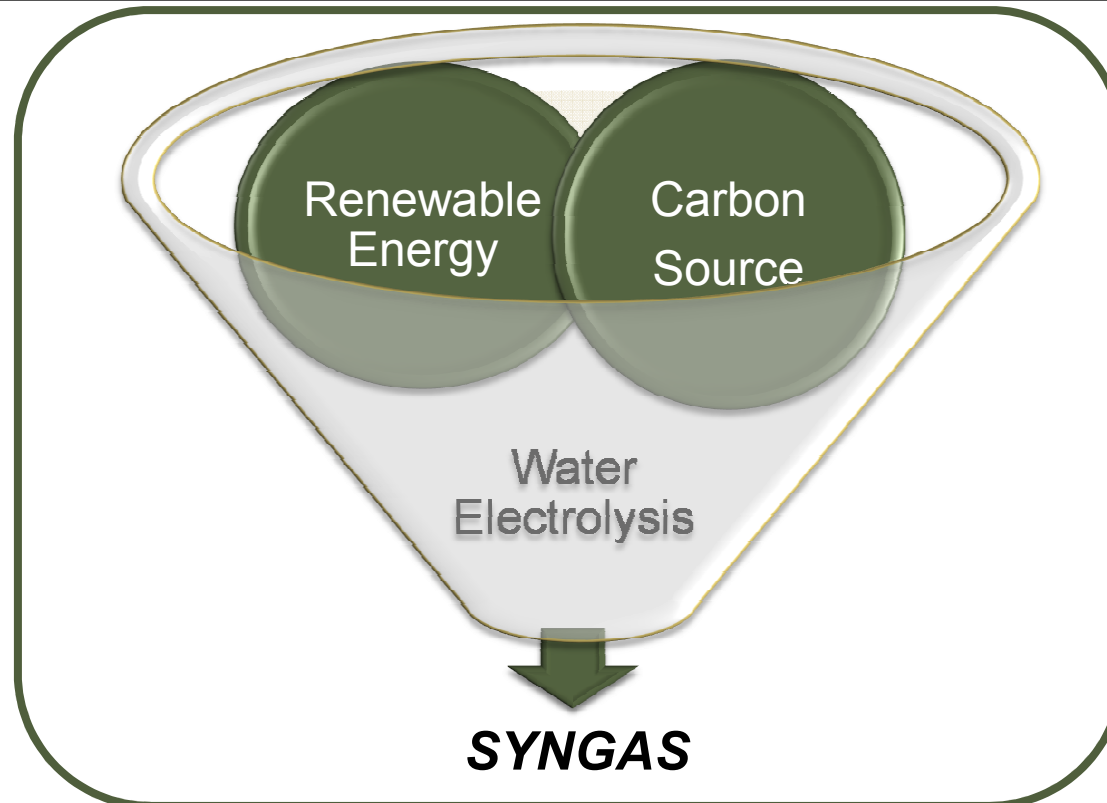
... contribute to reach low carbon targets

- Without the need for heavy investments to replace the existing platform

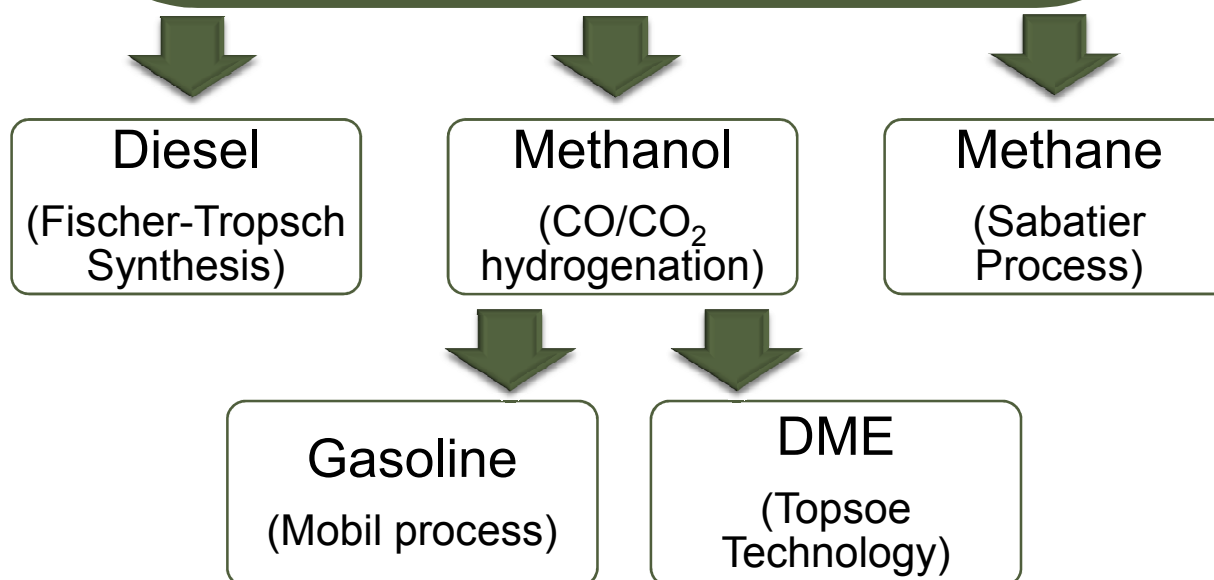
... allow the development of more attractive technologies to follow their learning path

- Hydrogen or Fuel Cells (mature technology)

Power
and
Carbon
to
Liquid
fuel



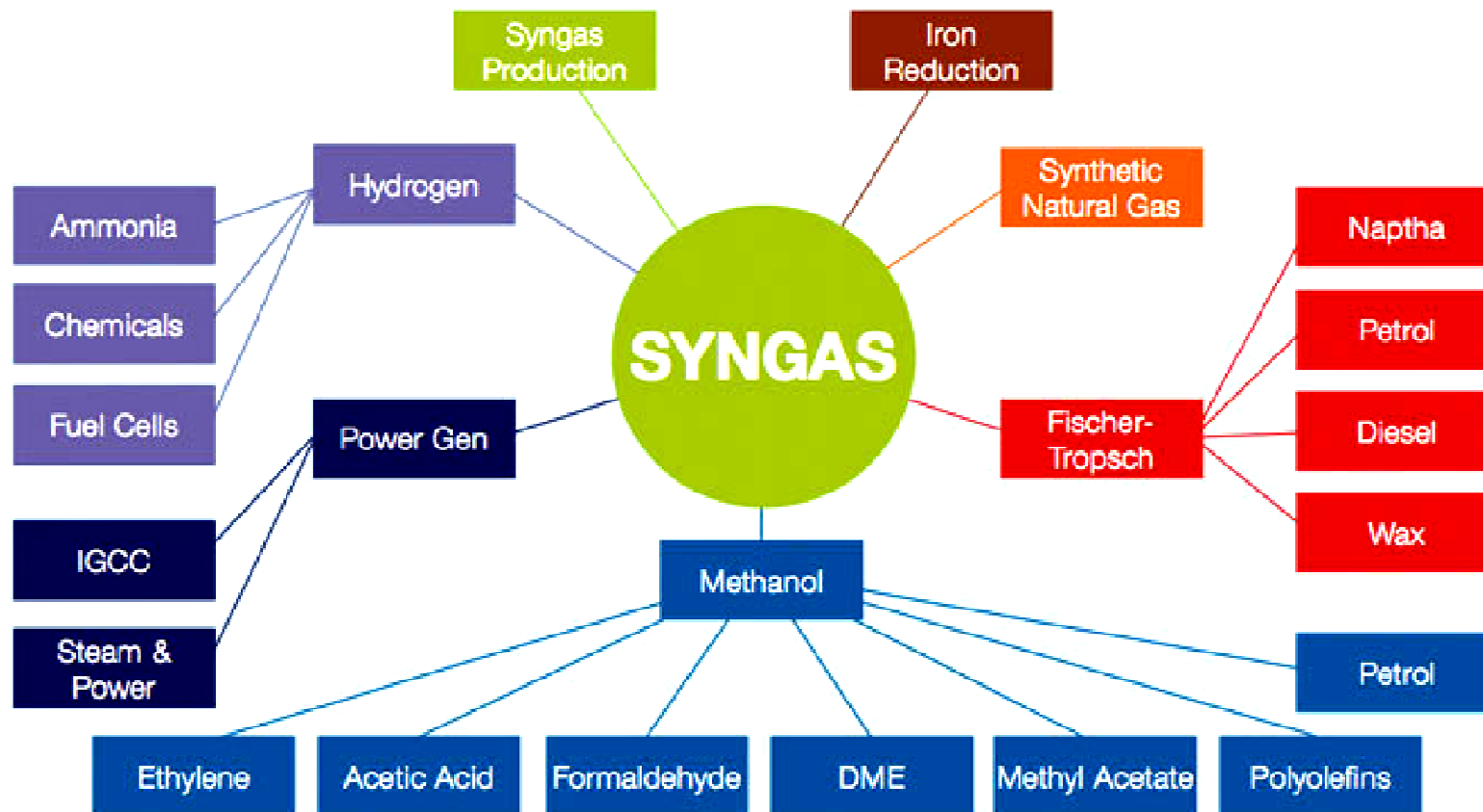
ELECTROFUEL[®]
CONCEPT



Syngas production by ELECTROFUEL®

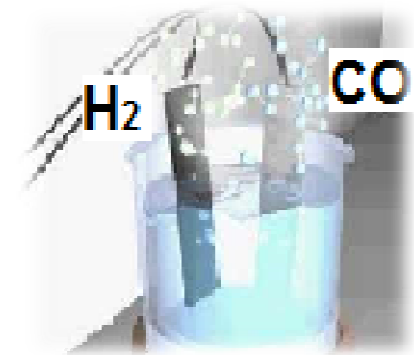
- One step from water electrolysis...
 - ... without separation of gases
 - ...with the use of carbon/graphite plates as electrodes and alkaline electrolyte
- Oxygen, on the anode, reacts with carbon from the electrode, producing CO and CO₂
 - $\text{C} + 2 \text{H}_2\text{O} \rightarrow \text{CO}_2 + 4 \text{H}^+ + 4 \text{e}^-$
 - $\text{C} + \text{H}_2\text{O} \rightarrow \text{CO} + 2 \text{H}^+ + 2 \text{e}^-$
- Hydrogen is released directly from the cathode
 - $\text{H}_2\text{O} + 2 \text{e}^- \rightarrow 2 \text{HO}^- + \text{H}_2$
- Syngas is then formed and can be used as a raw material for synthetic fuel production

Syngas and its Applications...



Advantages of this technology...

- Use of renewable energy as power source
 - Solar or wind...
- Electrolyzers: cheap and easy to build
- Able to compete with the conventional technologies:
 - Steam reforming, coal gasification...
- Renewable energy:
 - Stored in liquid state (diesel, gasoline) at a competitive cost
- Due to its simplicity:
 - economically feasible in small scale units

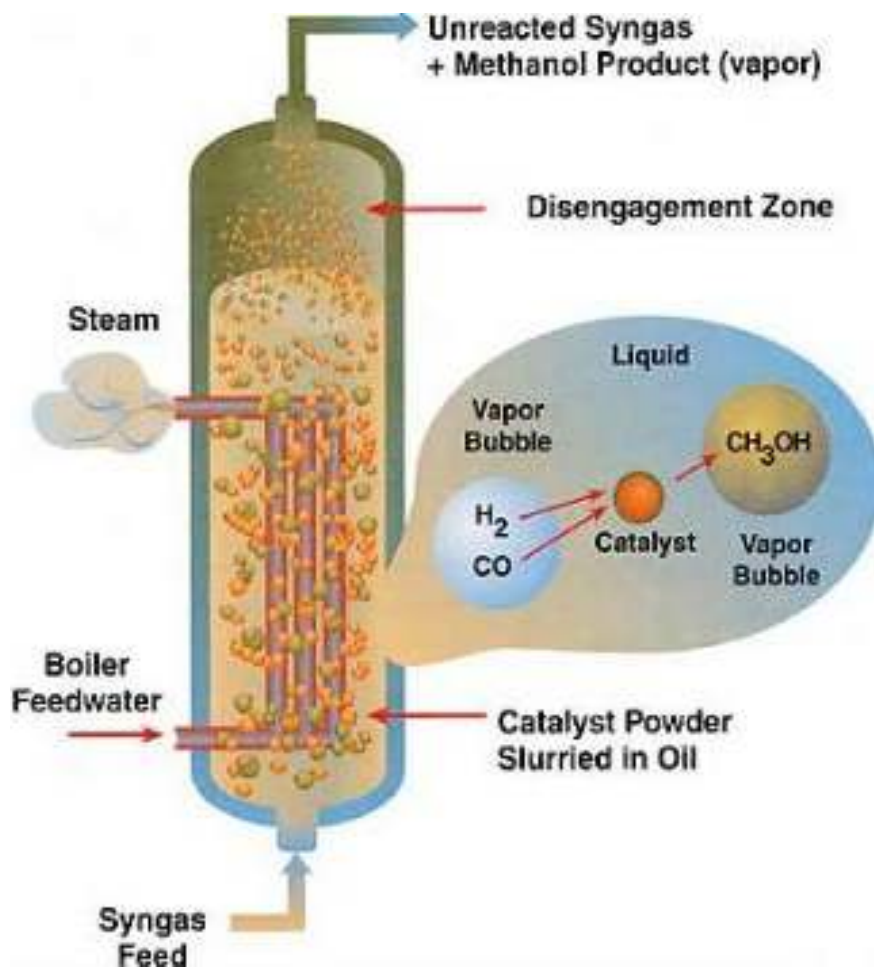


Syngas to Liquid Fuels...

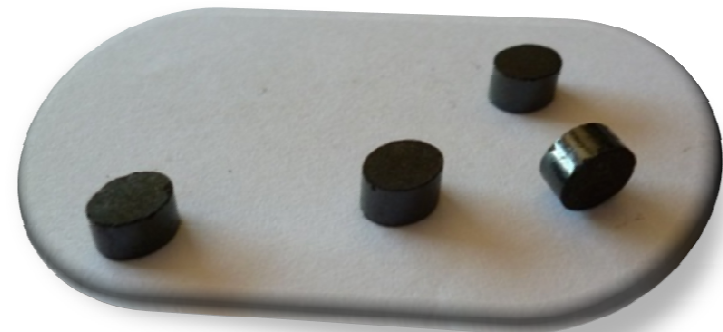
- Through a catalytic reaction
- Highly exothermic
- Intensive research to improve reaction conditions:
 - Pressure, temperature, catalyst activity...



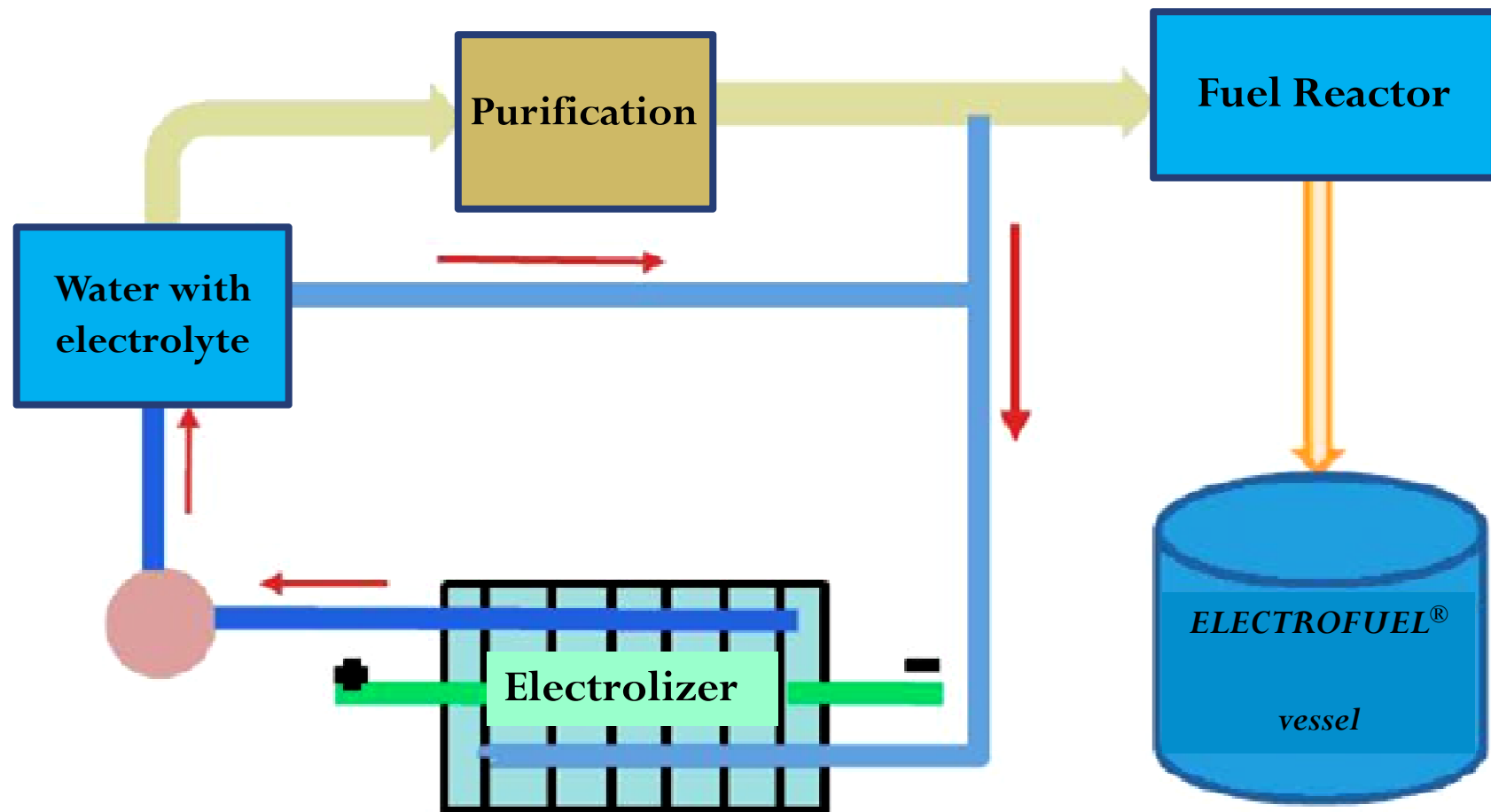
- Project partner:
 - Working on the best catalyst to produce methanol
 - $\text{CuO} + \text{ZnO} + \text{Al}_2\text{O}_3 + \text{MgO} \rightarrow$ Reference catalyst for testing



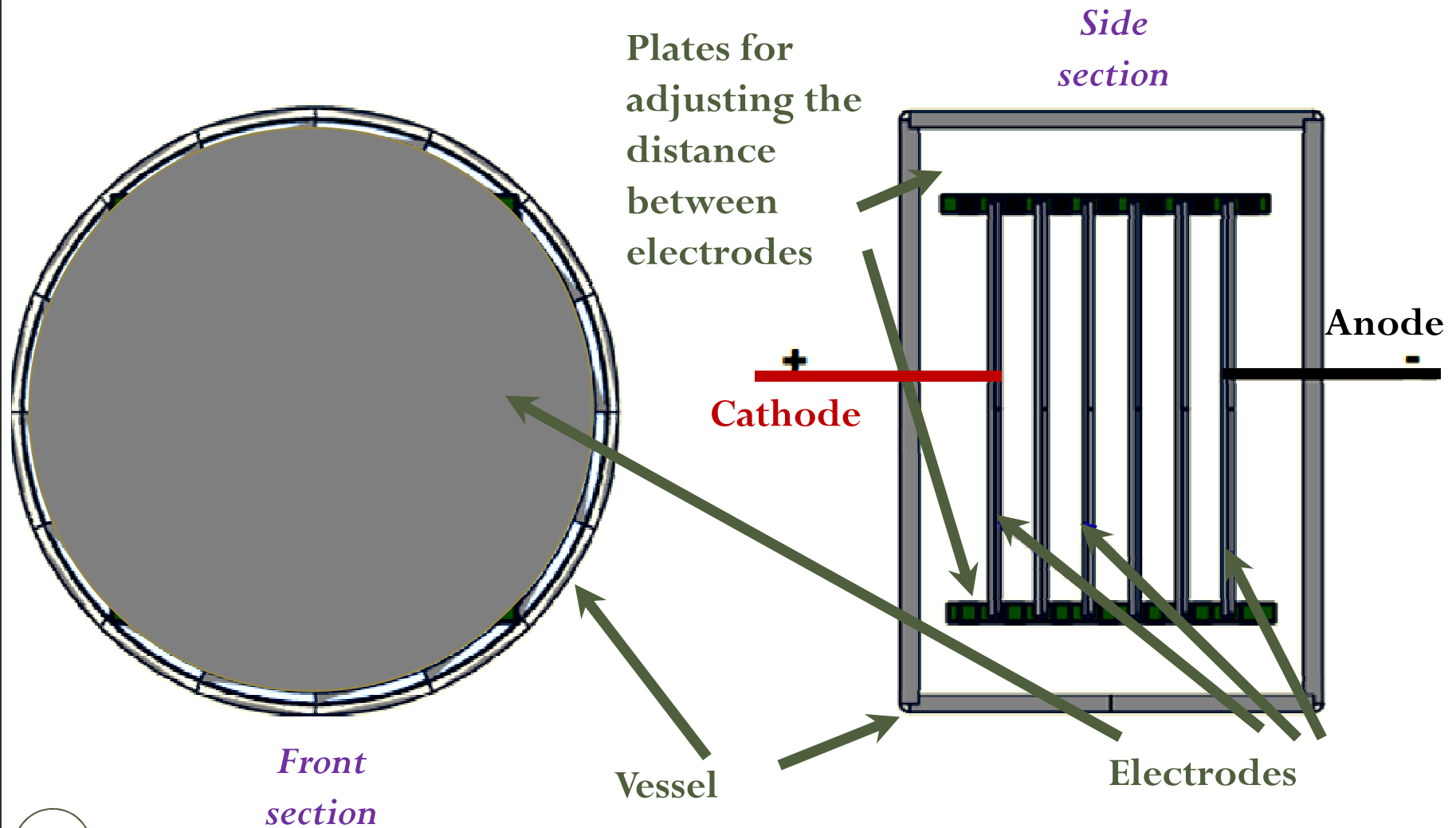
SLURRY REACTOR

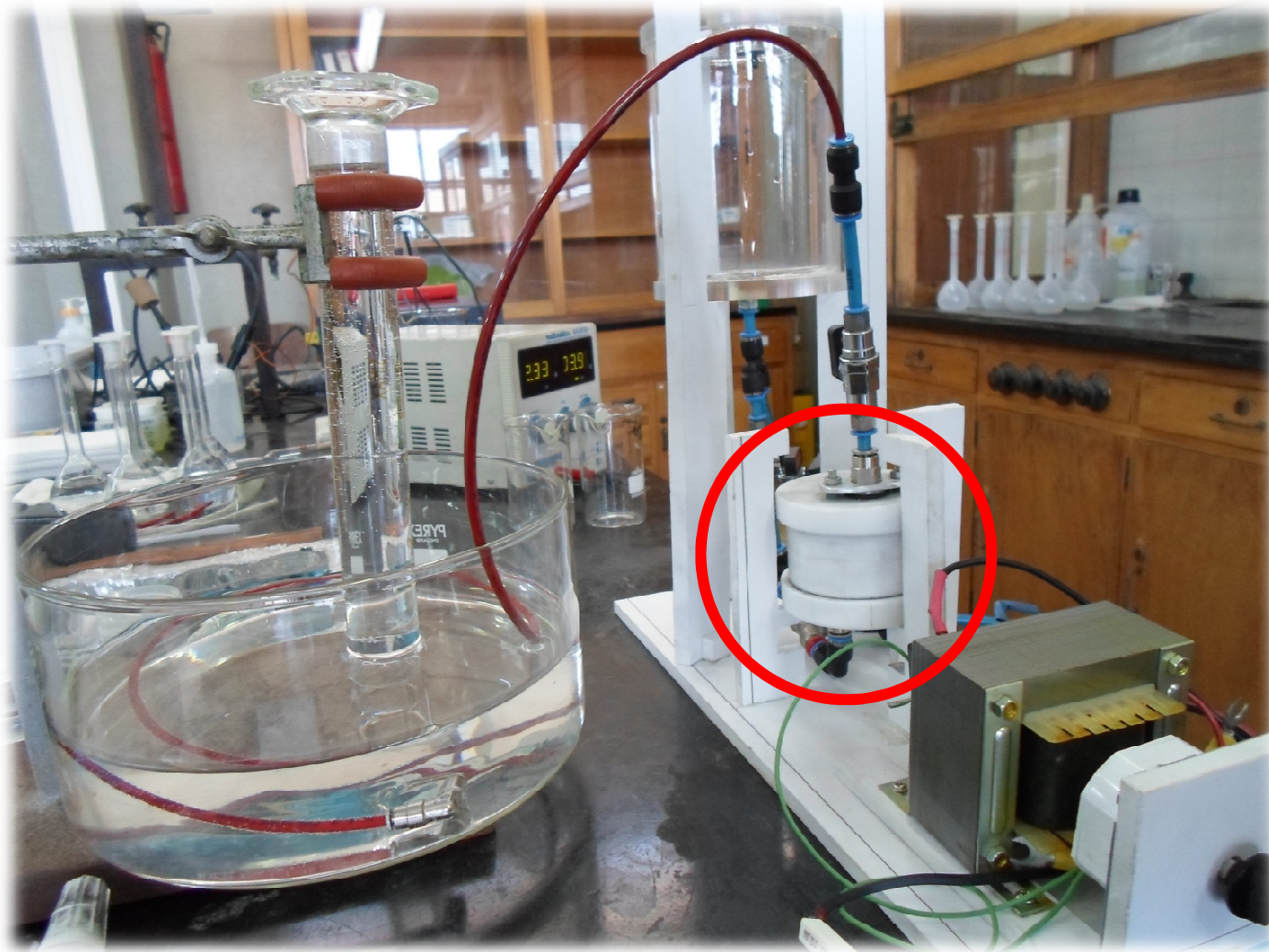


ELECTROFUEL[®] Reactor...



Electrolyzer Diagram...





Laboratory set-up

Where are we?

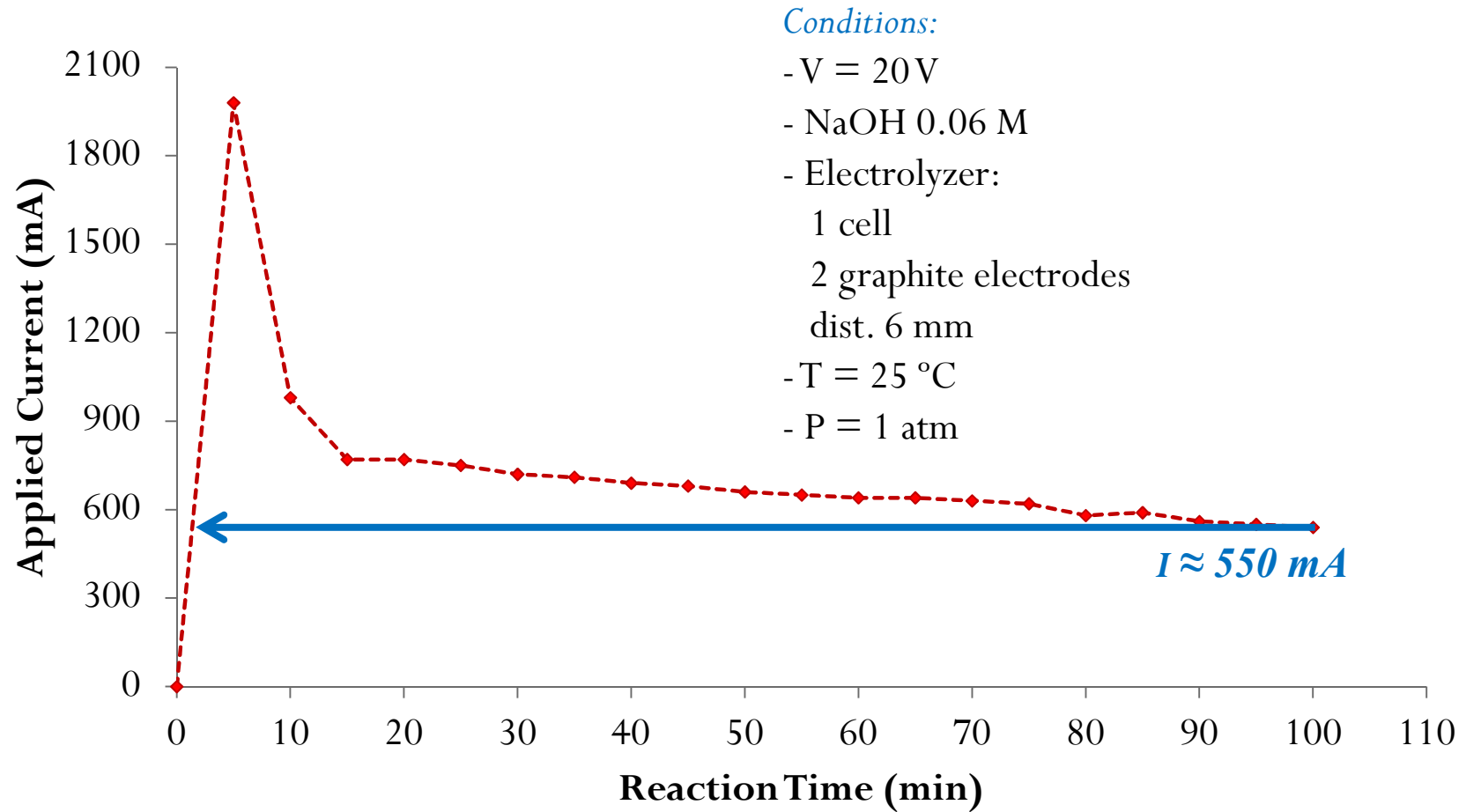
- Provisional Patent Registration
- Proof concept → Syngas
- COMPETE: Portuguese Innovation Incentive Schemes (Project 38940)
- Laboratory models undergoing:
 - Optimization and evaluation studies



Where are we headed?

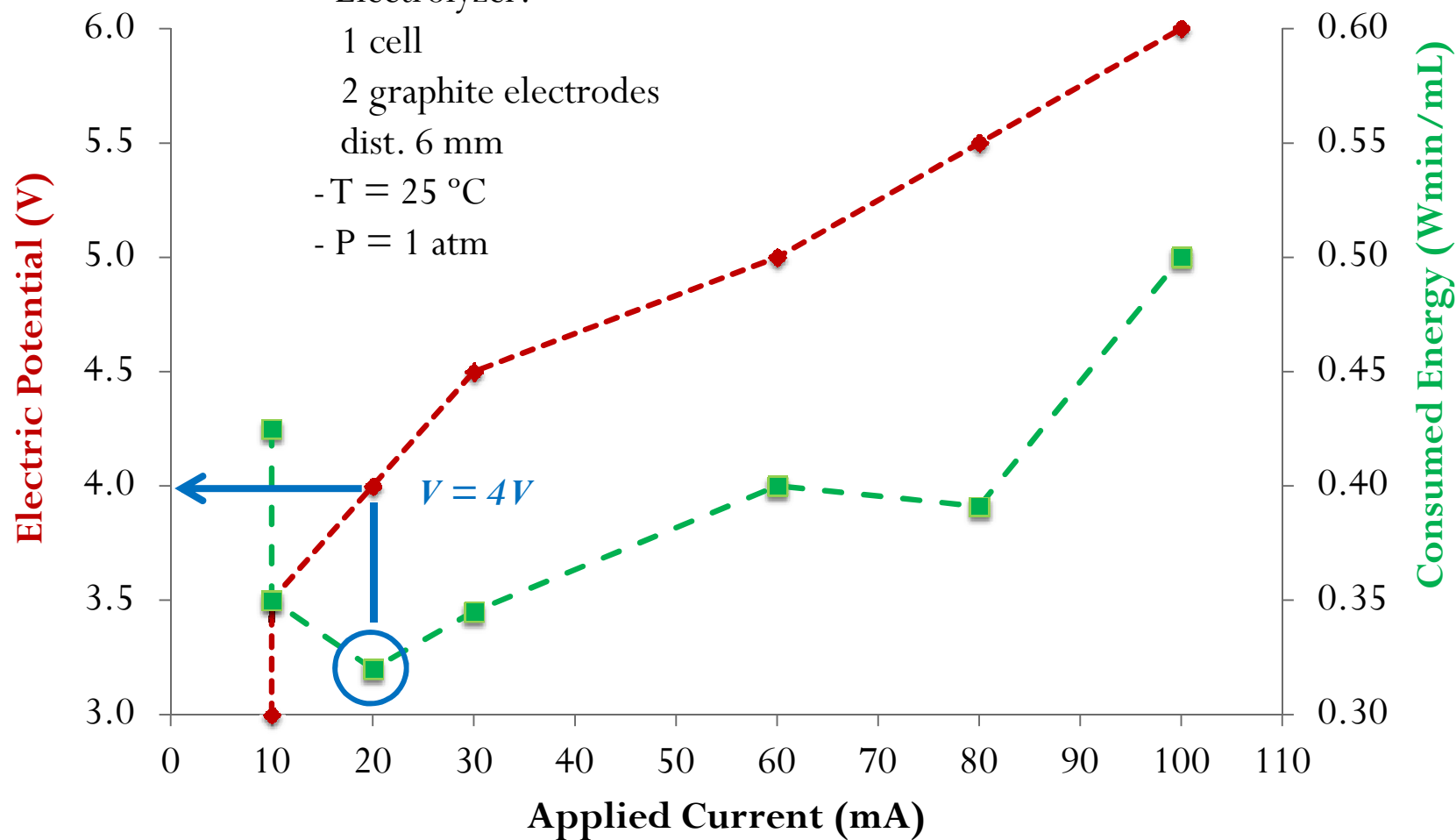
- Catalytic reactor to produce Methanol and DME
- First Industrial Prototypes tests:
 - 1 L/h and 10 L/h of Methanol / DME
- Motorization tests
- Scale-up to 100 L/h of Methanol / DME
- Demonstration plan
- Patent protection

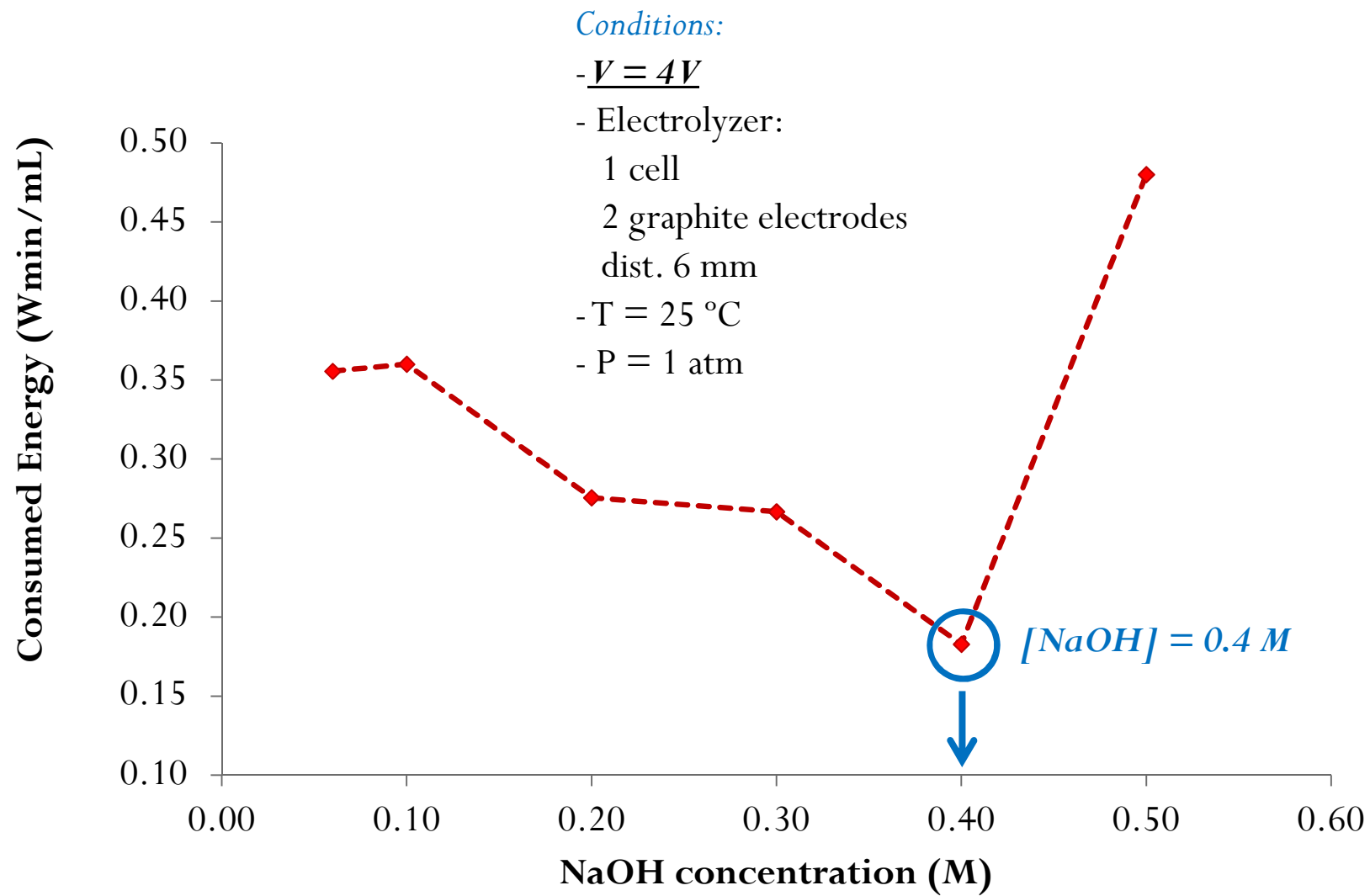
Preliminary Tests...



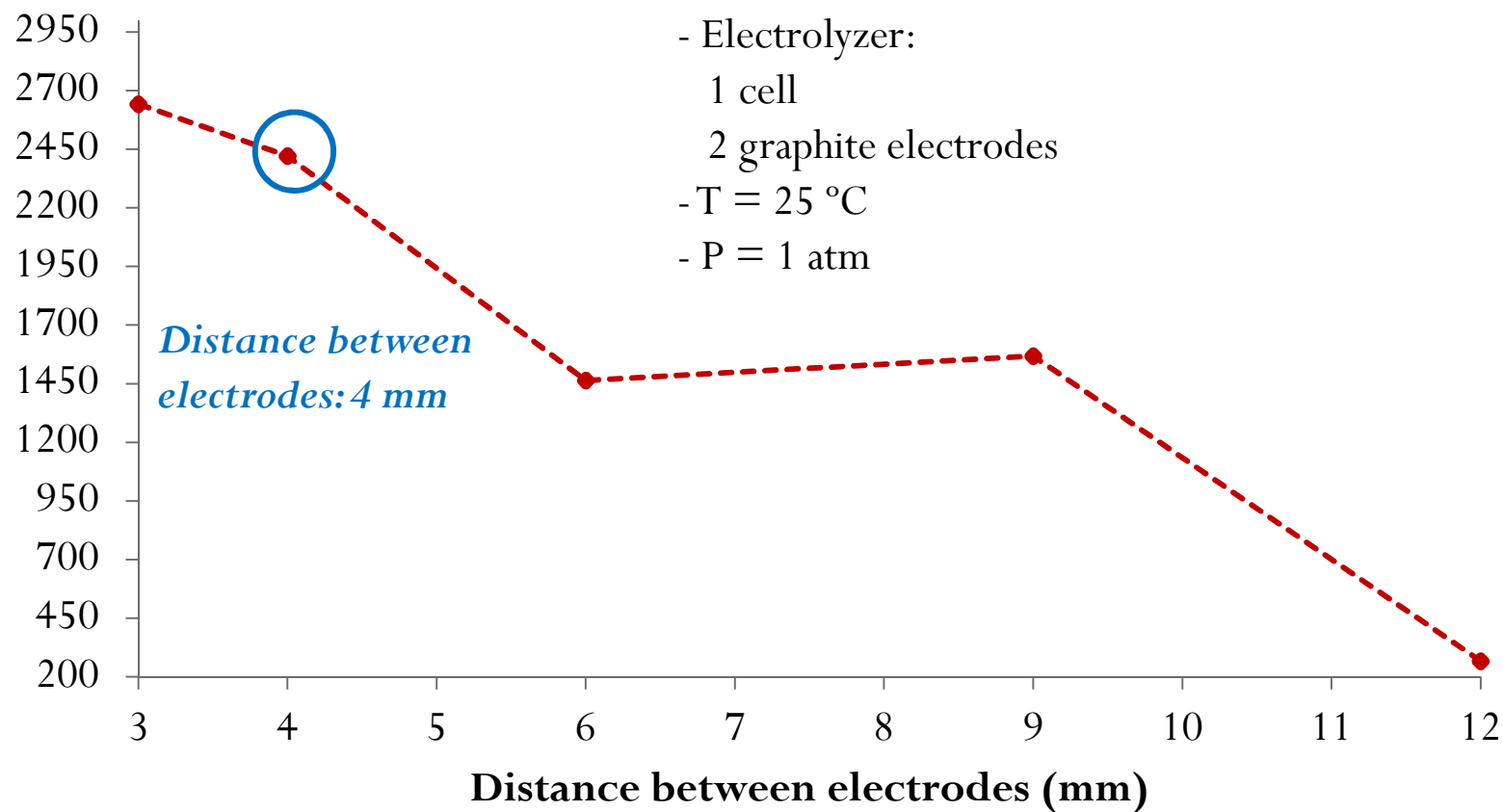
Conditions:

- NaOH 0.06 M
- Electrolyzer:
 - 1 cell
 - 2 graphite electrodes
 - dist. 6 mm
- $T = 25\text{ }^{\circ}\text{C}$
- $P = 1\text{ atm}$





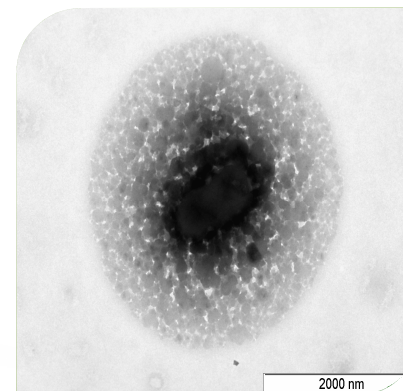
Applied Current (mA)



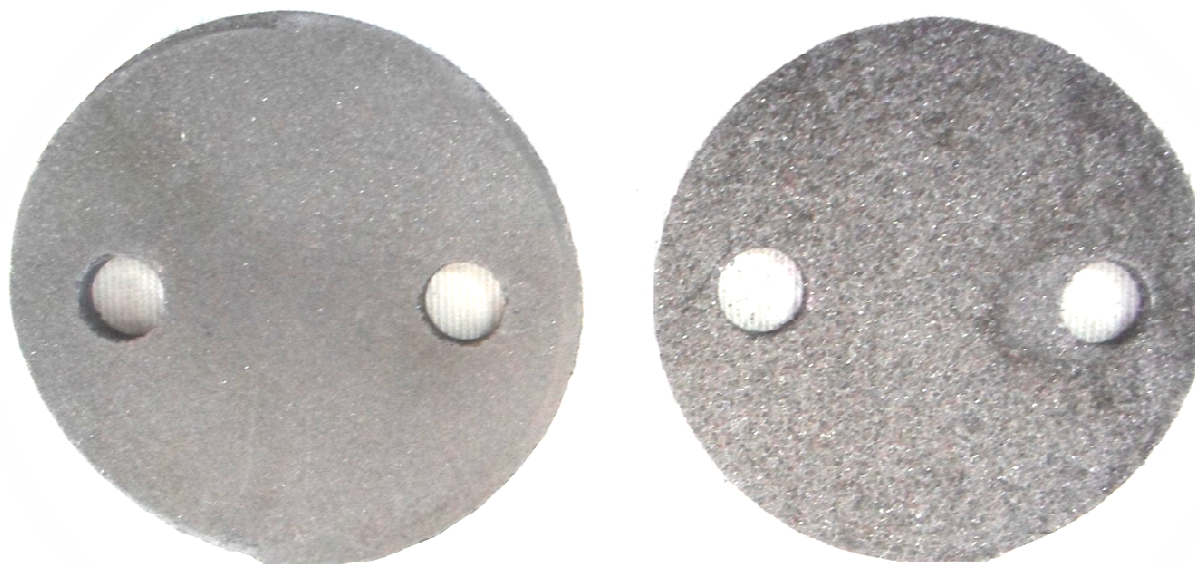
- ***Graphite Electrodes Loss***

Conditions:

- $V = 4\text{ V}$
- NaOH 0.4 M
- Electrolyzer:
 - 1 cell
 - 2 graphite electrodes
 - dist. 4 mm*
- $T = 25\text{ }^{\circ}\text{C}$
- $P = 1\text{ atm}$



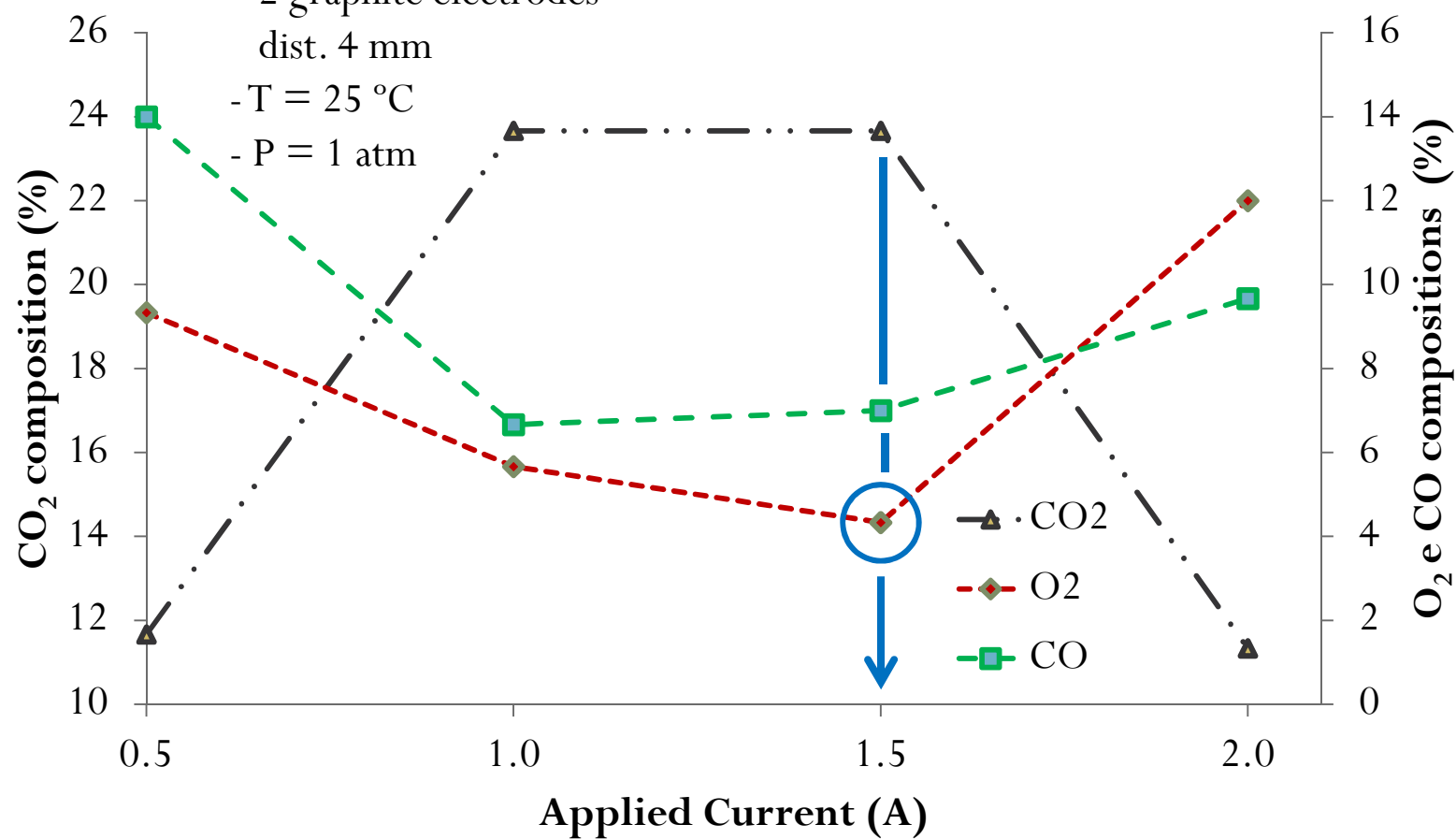
- Formation of nanocarbon particles



- Anode $\approx 1.5\%$ less mass after a 7 hours reaction
- Some of the mass lost is gained on the cathode

Conditions:

- $V = 4\text{ V}$
- $\text{NaOH} = 0.4\text{ M}$
- Electrolyzer:
 - 1 cell
 - 2 graphite electrodes
 - dist. 4 mm
- $T = 25\text{ }^{\circ}\text{C}$
- $P = 1\text{ atm}$



- *Gas analysis*

- With a best optimization we were able to achieve an interesting composition of syngas as follows (dry basis):

H₂	70 %
CO	10 %
CO₂	16 %
O₂	4 %
Others (hydrocarbons)	≈ 0 %

- *Steel + Graphite vs. Graphite*



Electrodes

H₂

Graphite

70 %

Steel + Graphite

58 %

CO

10 %

4 %

CO₂

16 %

28 %

O₂

4 %

10 %

Others (hydrocarbons)

≈ 0 %

≈ 0 %

Further tests still on-going ...

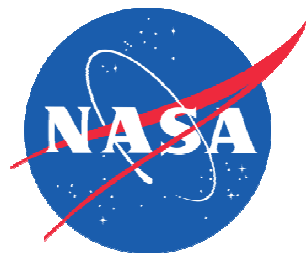
- Hydrocarbons were found on the gas analysis
- Temperature influence is not yet fully explored
- Pressure influence is not yet fully explored
- The destination of the nanocarbon particles:
 - Steam reforming...
- Use of catalysts spread in the electrolyte to improve syngas composition
 - Vanadium...

To summarize...

- Water electrolysis: renewable energy as electricity, carbon/graphite electrodes, without separation of gases and an alkaline electrolyte → syngas
- We reached 10 % of CO and 70 % of H₂, with 4 % of O₂
- Laboratory models for syngas production undergoing:
 - Optimization and evaluation studies → Temperature, pressure...
- Improve reaction conditions of methanol production:
 - Pressure, temperature, catalyst activity...

PROJECT SYM

QREN 38940



Thank You For Your Attention...

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